Machine learning and CFD can work together for surgery planning in the human nose

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The impressive anatomical variability of the human nose constitutes a significant challenge for the Ear, Nose and Throat (ENT) surgeons, who routinely perform surgical corrections of frequently encountered anatomic anomalies. Since functional information is not available to ENT doctors, such surgeries undergo large failure rates: e.g. more than one half of septoplasties fail[1].

Assessing such surgeries beforehand is an ideal task for data-driven methods. In fact, we have recently developed and demonstrated an approach[2] where machine learning is used to identify patient-specific anatomical pathologies together with the required surgical corrections. The approach trains and then uses a standard neural network (NN); however, by turning upside down a popular use of ML in fluid mechanics, instead of using the network to improve or facilitate CFD simulations, here CFD information (computed in a standard way) is taken advantage of to train the NN. Functional features related to the fluid mechanics of the nose are extracted from high-accuracy CFD simulations for nose anatomies derived from CT scans, and later used as input for a classification network. So far, highly resolved LES solutions (often labelled as quasi-DNS) obtained with the OpenFOAM finite-volumes CFD code have been used. Computing a single case is highly expensive in terms of CPU time; moreover, the subsequent data management and post-processing effort required to extract the feature(s) needed for training the NN is significant.

The subject of the present contribution is the discussion of the type of CFD solution that grants flow features which are informative enough for an effective training of the neural network. The nose flow is challenging, and it is known[3] that high-accuracy CFD is needed to obtain a good solution, as previously studied by many (see for example figure 1). However, high-accuracy CFD may be unnecessary here: a less expensive computational approach (in terms of both CPU and data management cost) may yield flow features that, while less accurate, still provide an adequate informative content.

The present study thus constitutes a necessary step before scaling up the database needed for training a full-scale NN. While in previous work approx. 300 cases have been used for the feasibility study, we believe that about one order of magnitude more cases are needed for the faithful and general prediction of nasal breathing difficulties and their surgical correction.

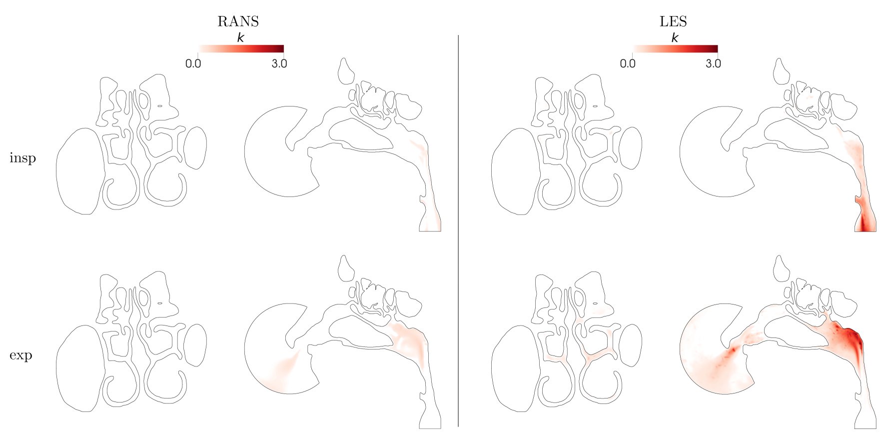

Figure 1: Turbulent kinetic energy k, as computed from a RANS (left) and a LES (right).

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[2] Schillaci A., Pipolo C., Boracchi G. and Quadrio M. 2024. Enhancing Machine Learning with Computational Fluid Dynamics, *J. Fluid Mech.*, in preparation

[3] A.Schillaci & M.Quadrio, 2022. Importance of the numerical schemes in the CFD of the human nose. *J. Biomechanics* **138**